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NOL PROJECT 152

AFSWP 262

AIRBLAST PEAK PRESSURES ALONG THE WATER SURFACE FROM SHALLOW UNDERWATER EXPLOSIONS

by

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ABSTRACT: The decrease of airblast peak pressure with distance along the water surface has been studied for shallow underwater explosions. The slopes of the pressure-distance curves for the region observed (45 to 200 charge radii) are much lower than those from a charge in the air. Cube root scaling of the pressure applies for a weight range of 20 to 4200 lbs.

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NAVORD Report 2571 1 August 1952

This report presents the results of airblast measurements made on charges fired in a study of the base surge under Task NOL-152. Because this program was not set up primarily as an airblast study, the range of conditions is not so great as might be desired for some purposes. However, it is believed that the data given here will be useful in certain weapon evaluation studies. The report is intended for information only. Any opinions expressed herein are those of the author.

The author wishes to acknowledge the very helpful assistance given him in devising and setting up the recording equipment by J. P. Slifko, R. S. Price, B. W. Scott and J. B. Dempsey.

E. L. WOODYARD
Captain, USN
Commander

PAUL M. FYE
By direction

TABLE OF CONTENTS

AIRBLAST PEAK PRESSURES ALONG THE WATER SURFACE FROM SHALLOW UNDERWATER EXPLOSIONS

INTRODUCTION

There is very little information available on the airblast from underwater explosions. In order to predict the effects of large underwater explosions on moored ships, harbor facilities, airplanes and other structures, data on airblast effects under various conditions are necessary. Although the results reported here cover only a very limited range of conditions, it is believed that the data will provide a sound basis for extrapolations. Only peak pressures were measured; it was not possible to record a complete pressure-time history of the blast wave.

The shock velocity method [a]* of determining air blast peak pressures was used. The velocity of sound in air and the component of wind velocity along the gauge line were obtained for each shot by firing two detonators just prior to the main charge. Measurements were made on the equivalents of 20, 101, 600 and 4200-lb TNT charges.

EXPERIMENTAL ARRANGEMENTS

Instrumentation and Rig. Nine tourmaline piezoelectric gauges, ranging from 3/4 in. to 2 in. diameter, were used as pickups for the airblast shockwaves. The gauges were mounted in one line with the charge and were oriented face-on to the shockwave for fast response. Figure 1 is a sketch of the experimental arrangement. The distances between gauges shown are nominal; exact distances between the gauges were measured before each shot. Distances between gauges were accurate to within 1/16 in. The gauges were mounted 4 in. above the water surface except on about half of the 600 and 4200-lb tests on which gauge positions 2, 4, 6 and 8 were mounted 15 in. above the water surface.

The floating rig (Figures 2A,B) used to support the gauges consisted of two telephone poles 40 ft long, with additional buoyancy supplied by six oil drums. This was securely anchored in the desired position for each shot. The distance from the charge to the rig was varied from shot to shot to obtain a larger pressure range.

* Such letters refer to the list of references at the end of this report.

The signals were fed through 50 to 100-ft lengths of Simplex "signal-free" cable to a junction box (Figures 2C,D) where the nine cables were connected in parallel to one 500-ft length of RG41U cable. This, in turn, was connected to a field preamplifier (Figure 3A) and then thru an additional 600-ft length of RG41U cable, to a gain changer (Figure 4C) and a modified Dumont 208 oscilloscope [b,c]. The oscilloscope trace, along with simultaneous timing marks, was recorded on a 3-ft strip of film on a rotating drum camera. The timing source consisted of the signal from a crystal controlled multivibrator [b] which was fed into a second oscilloscope.

Beam brightening, beam displacement, and the firing of the two detonators and the main charge were synchronized by contacts on the shaft of the rotating drum camera which actuated the relay machine and beam brightener circuit (Figures 4A,B and 5). The contacts were offset so the succeeding stages of the relay machine were actuated approximately one revolution apart. The camera speed was varied from approximately 600 rpm to 200 rpm, depending upon the expected times of arrival of the shockwaves at the rig. Thus, the time intervals between the firing of the two detonators and between the second detonator and the charge ranged from approximately 100 to 300 milliseconds.

The firing circuit (Figure 3B) was isolated from ground at the instrument end to eliminate, as nearly as p ssible, groundloops between the gauge cable and the firing lines.

Charges. Seven demolition blocks of cast tetrytol plus half a block of Composition C-3 were considered to be equivalent to twenty pounds of TNT. The blocks were stacked in two layers, with these dimensions: 4 in. high, 8 in. wide, and 11 in. long. Each charge was oriented with the 8 x 11 in. surfaces horizontal and the 4 x 11 in. surfaces perpendicular to the gauge line.

Two 50-lb cast TNT Mk 14 demolition blocks and half a block of Composition C-3 were used for the 101-lb charges. These charges were cubes, each side being about 13 in. long, with the Composition C-3 placed on top. They were oriented with a face perpendicular to the gauge line.

For the larger weights, Mk 7 TNT-loaded depth charges were used, singly for the 600-lb and in groups of seven for the 4200-lb charges; all charges were placed upright. In the 4200-lb charge, six of the cylindrical Mk 7 depth charges were symmetrically spaced around the seventh, at which detonation was initiated. Approximately 4 lbs of Composition

C-3 was used to booster the 600 and 4200-lb charges.

The reduced charge depth, λ_c, was varied from 0 to about 0.5:

$$\lambda_c = R_c/W^{1/3}$$

Where R_c = vertical distance from the water surface to the center of the charge in ft
W = charge weight in lbs.

The experiments were performed in shallow water, with the charge set at the desired depth. The 20 and 101-lb charges were tied to stakes; the 600 and 4200-lb charges were placed on wood platforms at the proper depth. In some cases the charges rested on the river bottom. On some shots the bottom of the charge was level with the water surface ("surface level" shots).

The charge depth, water depth and λ_c are listed in Tables I through IV along with the peak pressures obtained for each shot.

RESULTS

Peak pressures were obtained from the shock front velocity measurements using the Rankine-Hugoniot equation relating peak pressure to shockwave velocity:

$$\frac{P_s}{P_o} = \frac{2\gamma}{\gamma + 1}\left[\left(\frac{U}{C}\right)^2 - 1\right]$$

where P_s is the peak pressure in excess of atmospheric pressure

P_o is the atmospheric pressure ahead of the shock

U is the velocity of the shock front in still air

C is the velocity of sound in still air

γ is 1.40 (ratio of specific heats for air).

Shock front velocity and sound velocity were determined from measurements made directly on the film record with a microcomparator.

Figures 6 through 15 give peak pressure as a function of reduced distance, λ, for various charge positions for the 20 and 101-lb charges:

$$\lambda = R/W^{1/3}$$

Where R = horizontal distance to the center of the charge in ft
W = charge weight in lbs.

In each figure, each symbol represents one shot, and each point is a single observation. A smooth curve was drawn by eye for each charge depth. As a standard for comparison, the pressure-λ line obtained from the surface level shots for the same charge weight is given on each figure.

The slopes of the pressure-λ curves from the underwater shots are significantly different from those of the surface level shots at the depths measured*. The crossover observed for some of the shallow shots is believed to be real. For the range of water depths covered, there is no indication that the proximity of the river bottom affected the magnitude of the peak pressure along the water surface.

The results from the 600 and 4200-lb charges are shown in Figures 16 through 19. There was no significant difference in peak pressure between the gauges at 4 in. and 15 in. above the water surface at the distances measured.

For scaling purposes, curves for peak pressure as a function of reduced charge depth, λ_c, are plotted in Figure 20 for reduced distances, λ, of 10 and 20. The points shown were taken from the lines drawn through the data on the pressure-λ plots. It is seen that air blast peak pressures along the water surface scale simply with the cube root of the charge weight.

* Were the slopes nearly constant for all depths, it would be possible to obtain a reasonable average value of "equivalent weight ratio" [d] for the underwater shots relative to the surface level shots. However, it is clear from Figs. 6 - 19 that such a weight ratio would refer to only one pressure. As an example, from Figure 8 the equivalent weight ratio would vary from about 0.3 at 14 psi to about 2.1 at 2 psi. Thus, equivalent charge weights appear to be meaningless in the region studied.

There are very few data available with which to compare these results. The slope of the pressure-λ curve for the 20 and 101-lb surface level charges is in fair agreement with that obtained from 50-lb cubical charges fired above the ground [e]. However, 1-lb spherical pentolite charges [f] fired above and just in water give quite different pressure-λ curves from those reported here.

It is interesting to note that peak pressures from some underground explosions [g] at $\lambda = 10$ decreased with increased charge depth at about the same rate as the data reported herein.

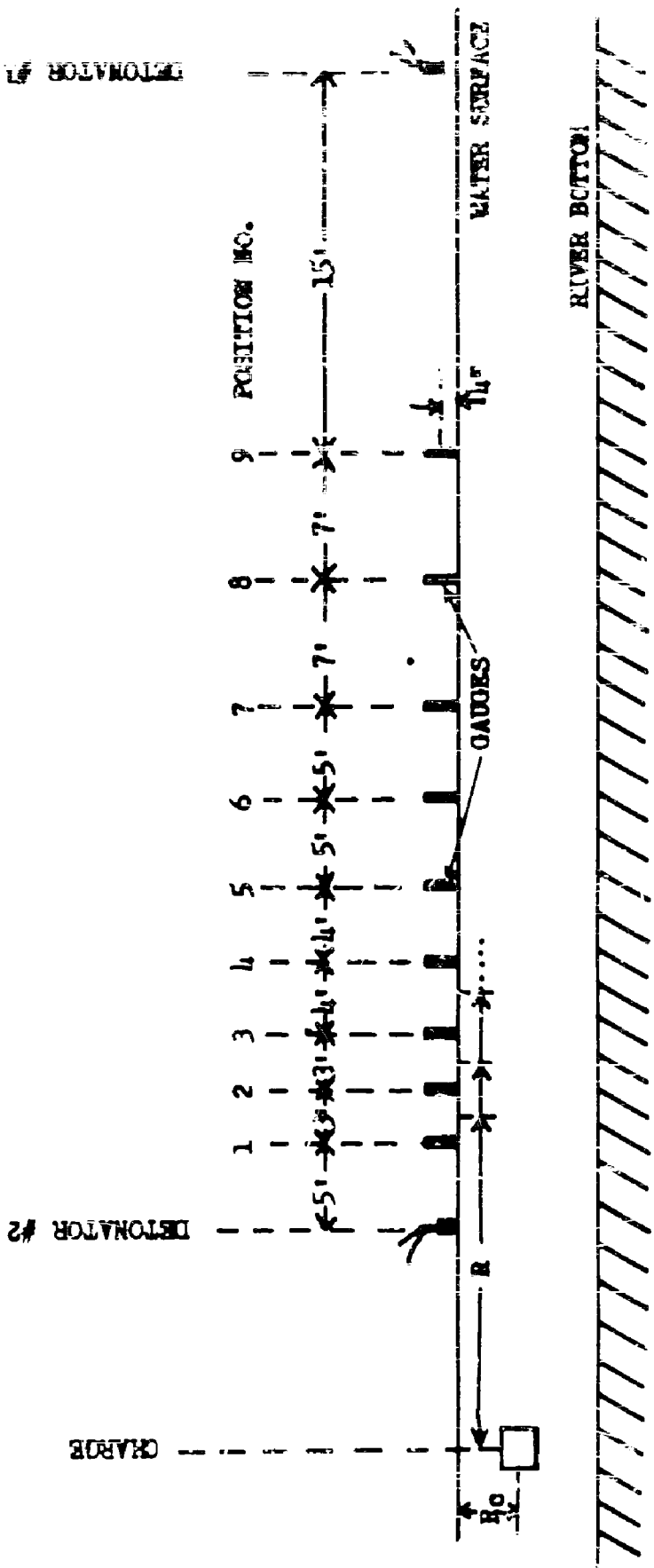

FIG. 1 EXPERIMENTAL ARRANGEMENT

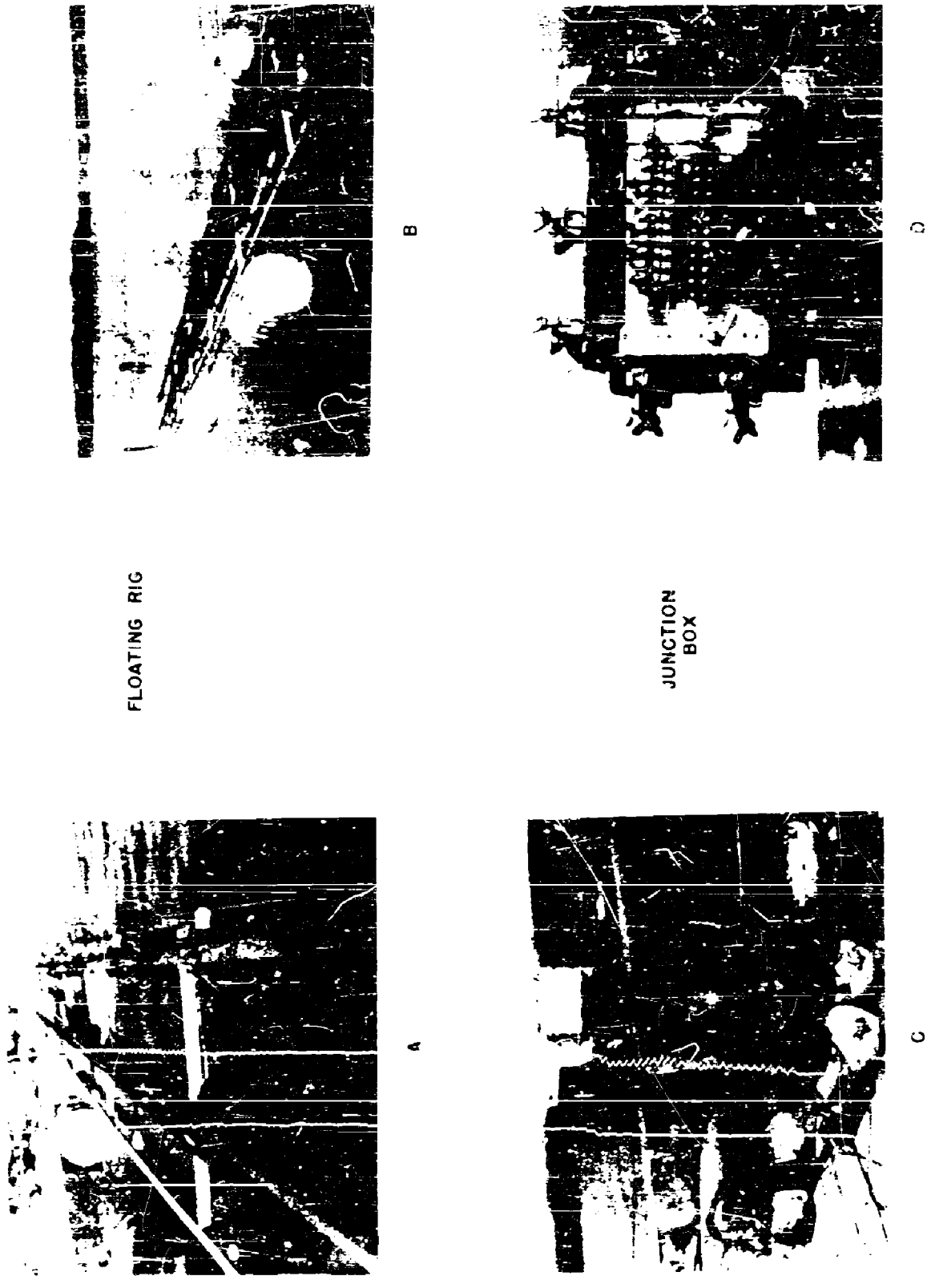

FIG. 2
FLOATING RIG AND JUNCTION BOX

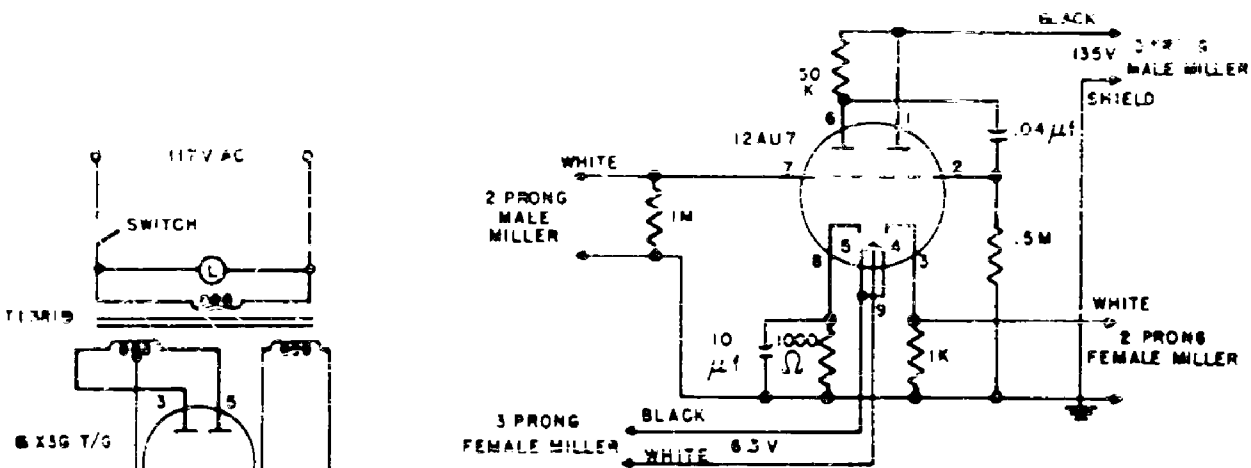

FIG. 3A PREAMPLIFIER

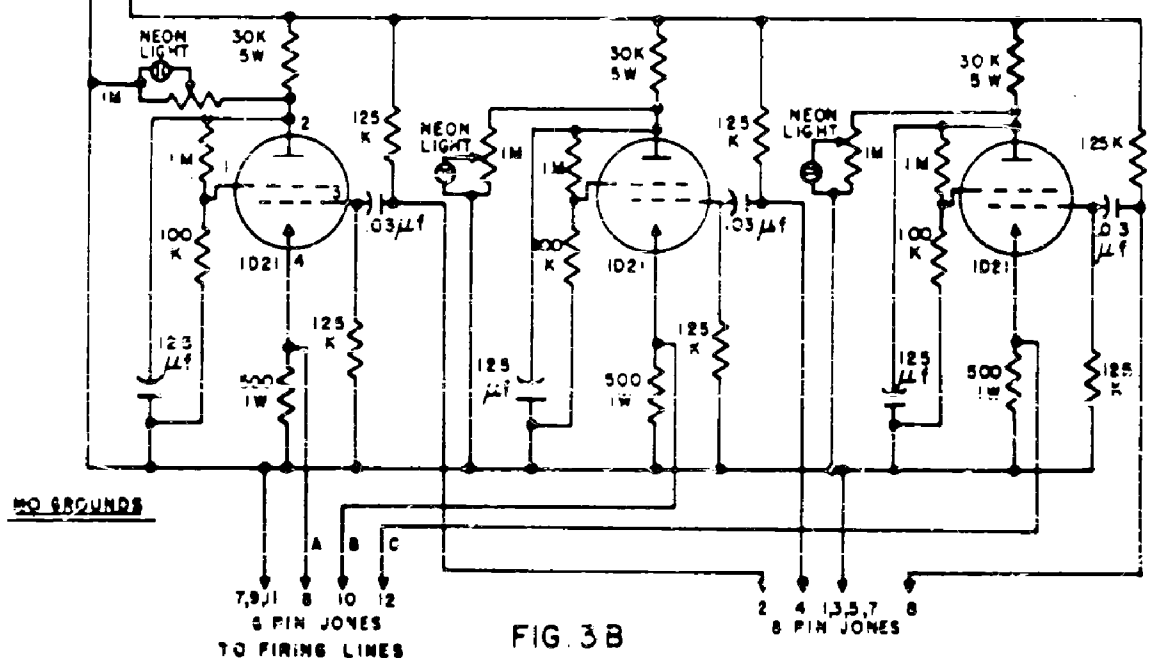

FIG. 3B
FIRING CIRCUIT

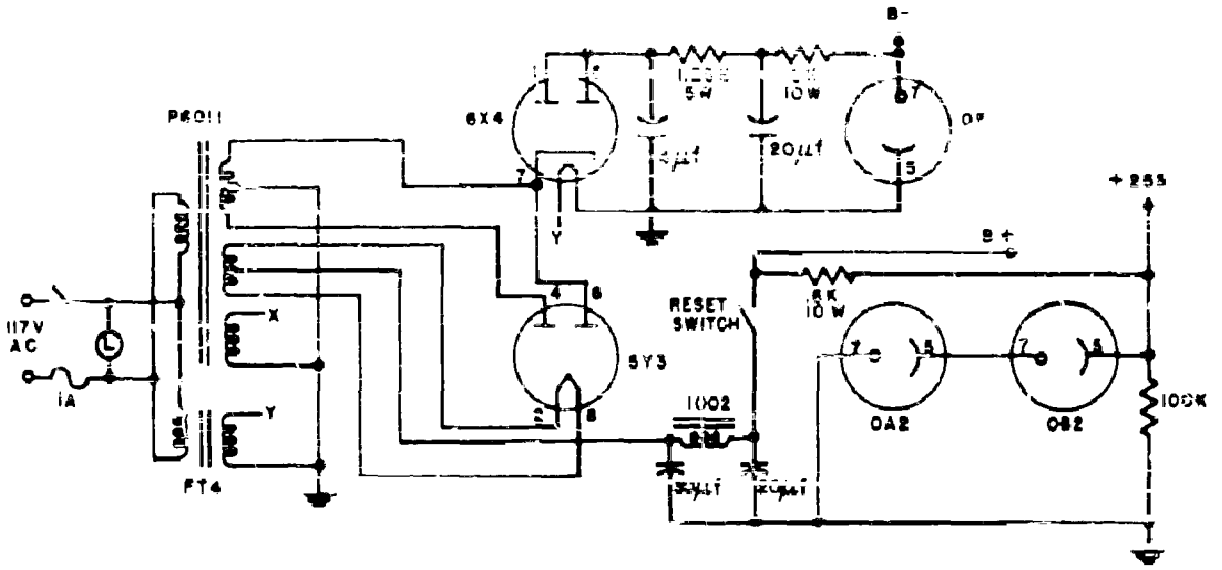

FIG. 4A POWER SUPPLY FOR RELAY MACHINE AND BEAM BRIGHTENER

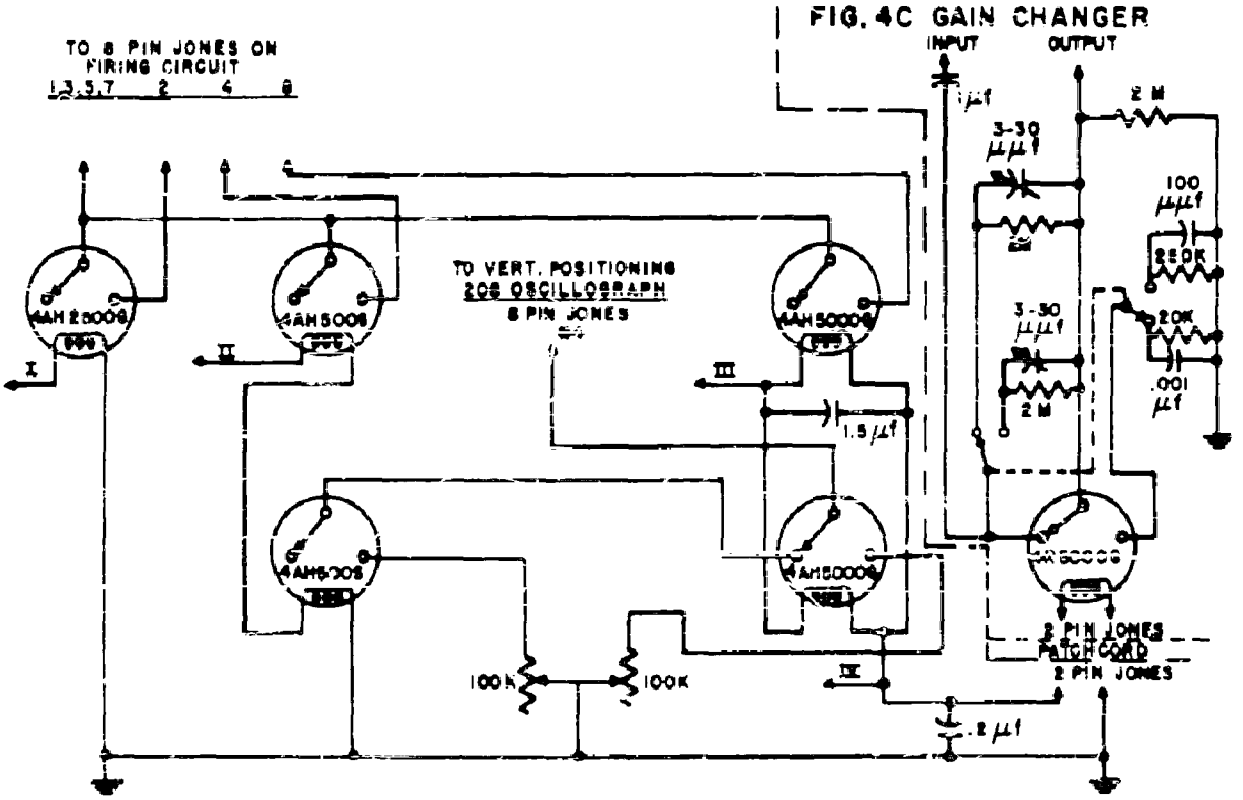

FIG. 4B RELAY MACHINE AND BEAM BRIGHTENER (RELAY CIRCUIT)

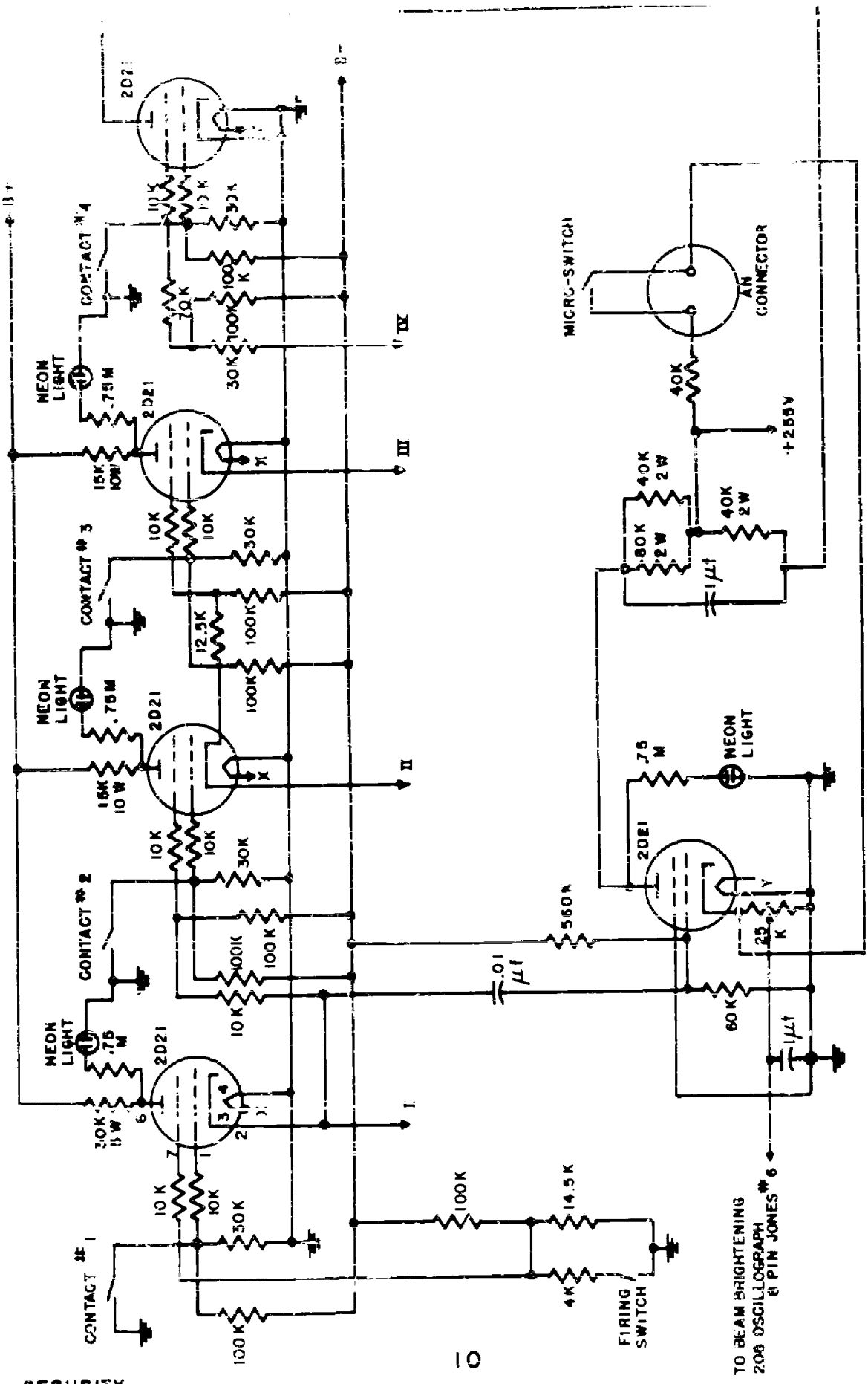

FIG. 5 RELAY MACHINE AND BEAM BRIGHTENER

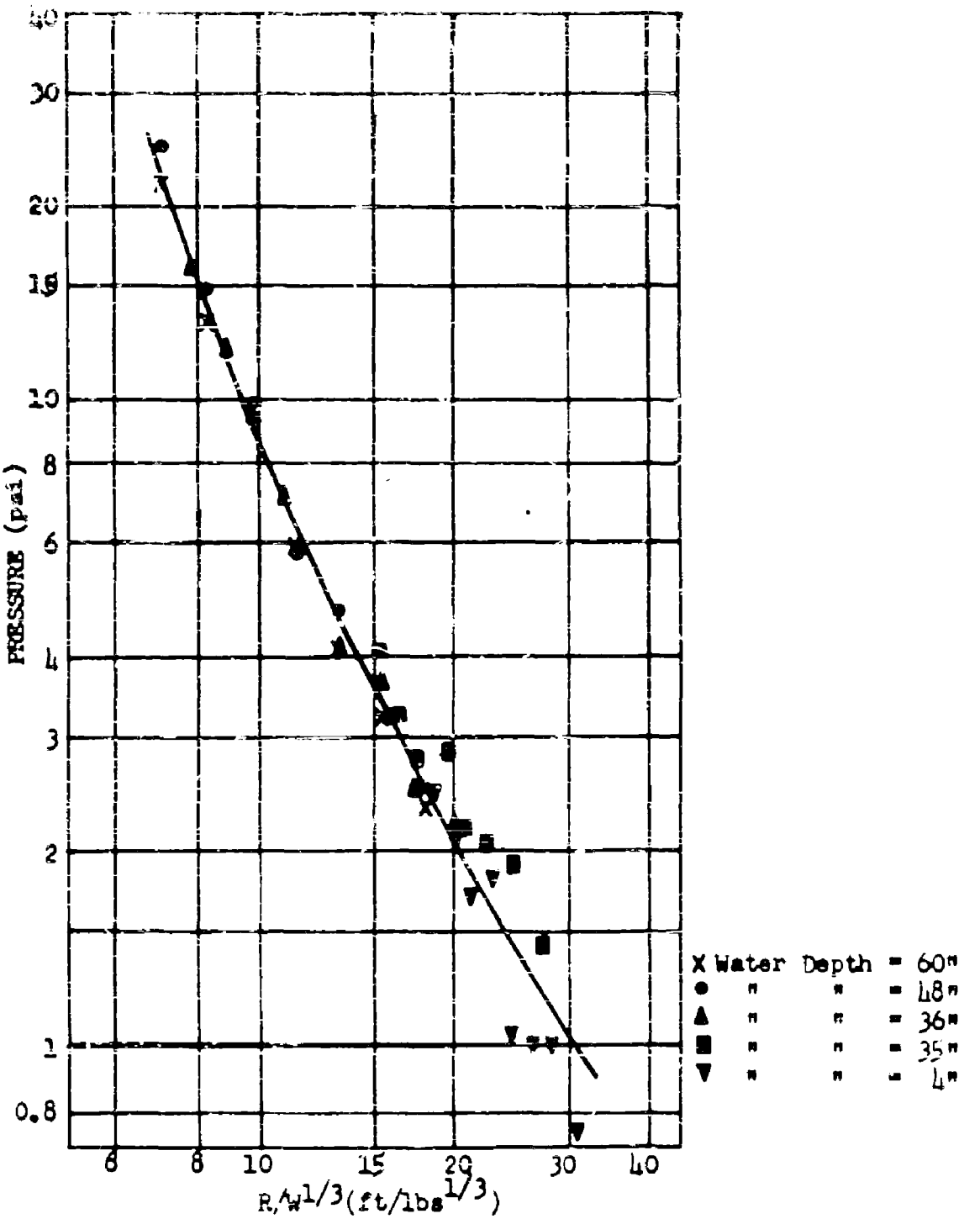

FIG. 6 PEAK PRESSURE vs REDUCED DISTANCE FOR 20-LB CHARGES BOTTOM OF CHARGE AT SURFACE (SURFACE LEVEL)

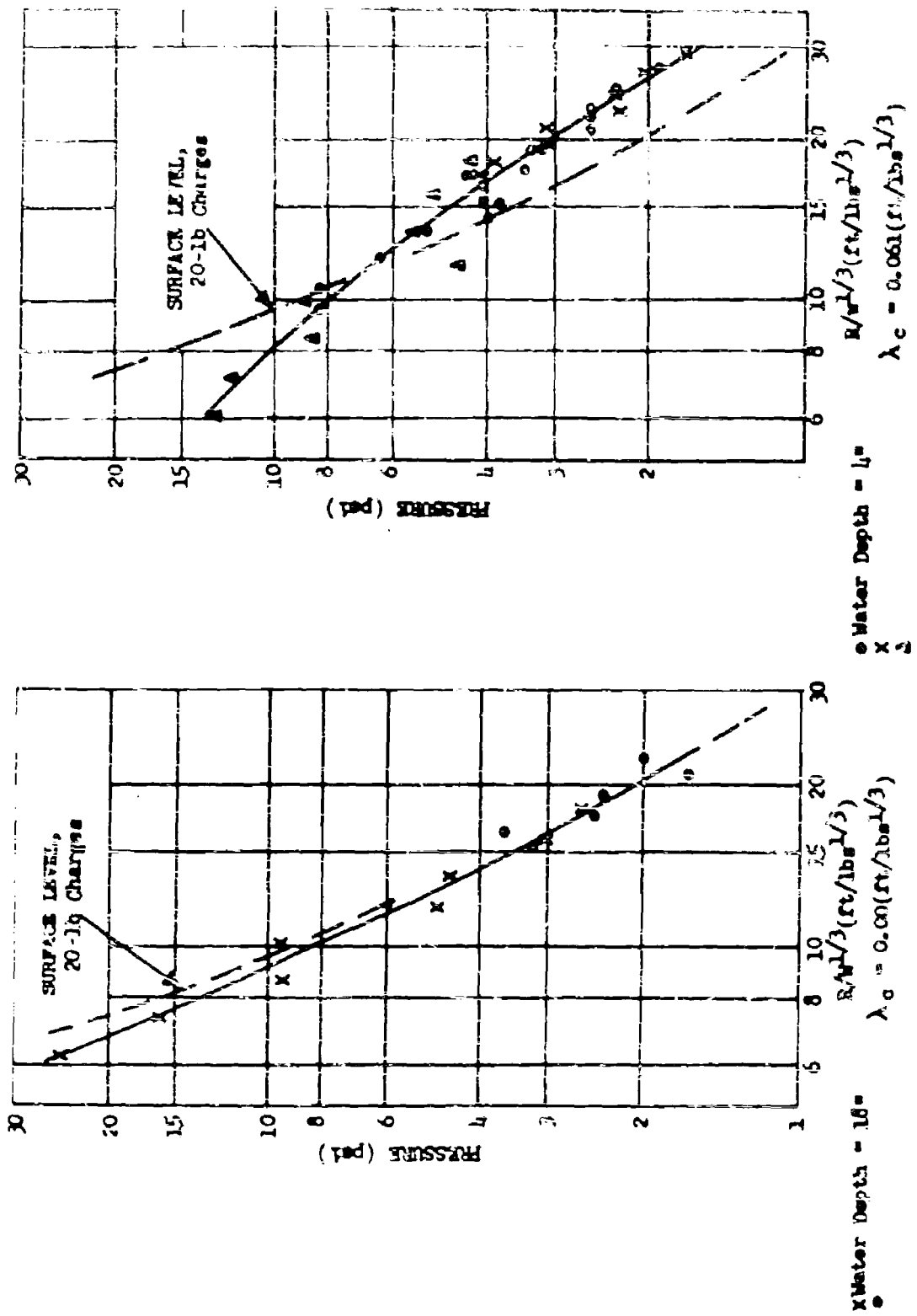

FIG. 7 PEAK PRESSURE vs REDUCED DISTANCE FOR 20-LB CHARGES

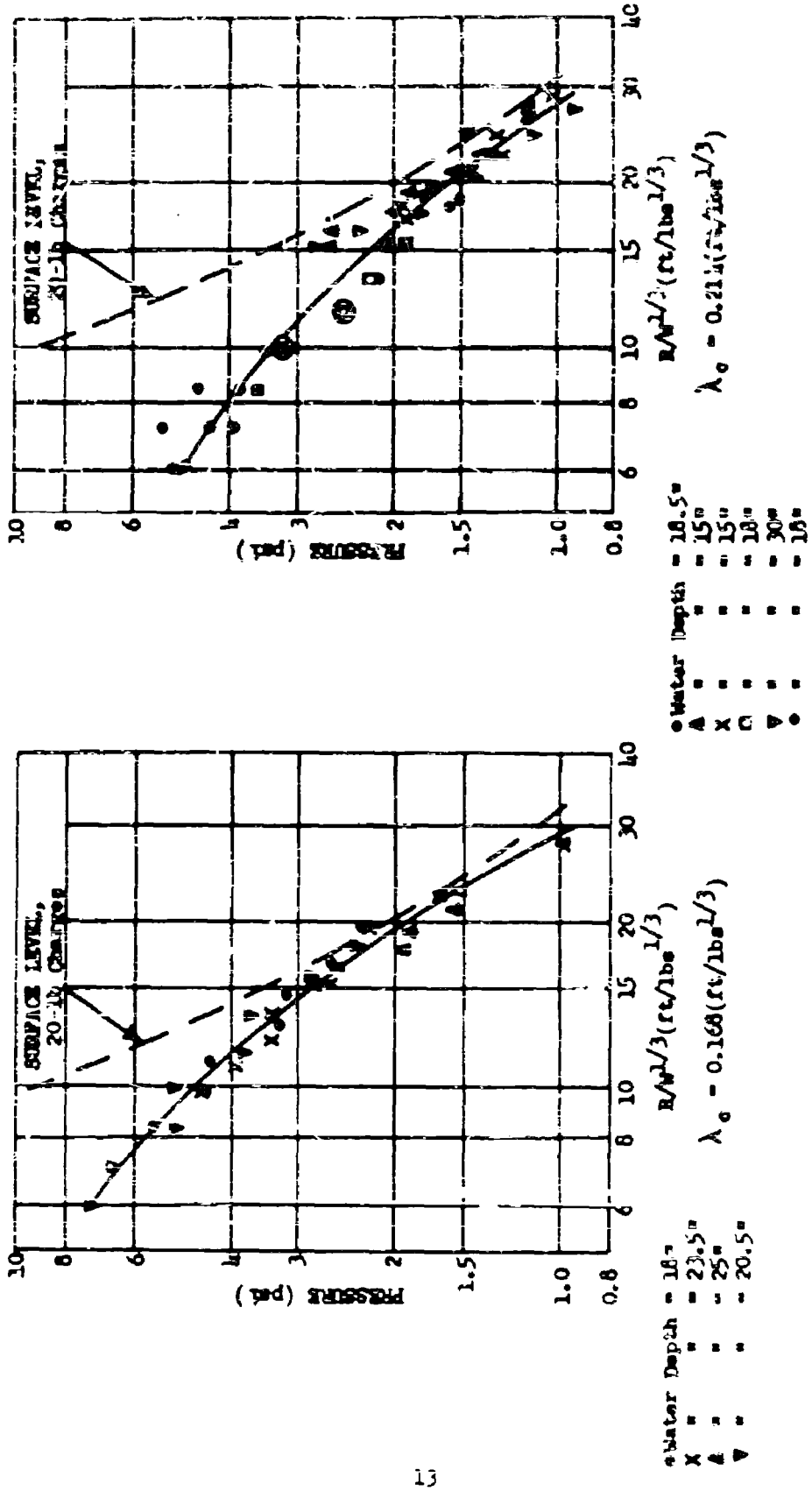

FIG. 8 PEAK PRESSURE vs REDUCED DISTANCE FOR 20-LB CHARGES

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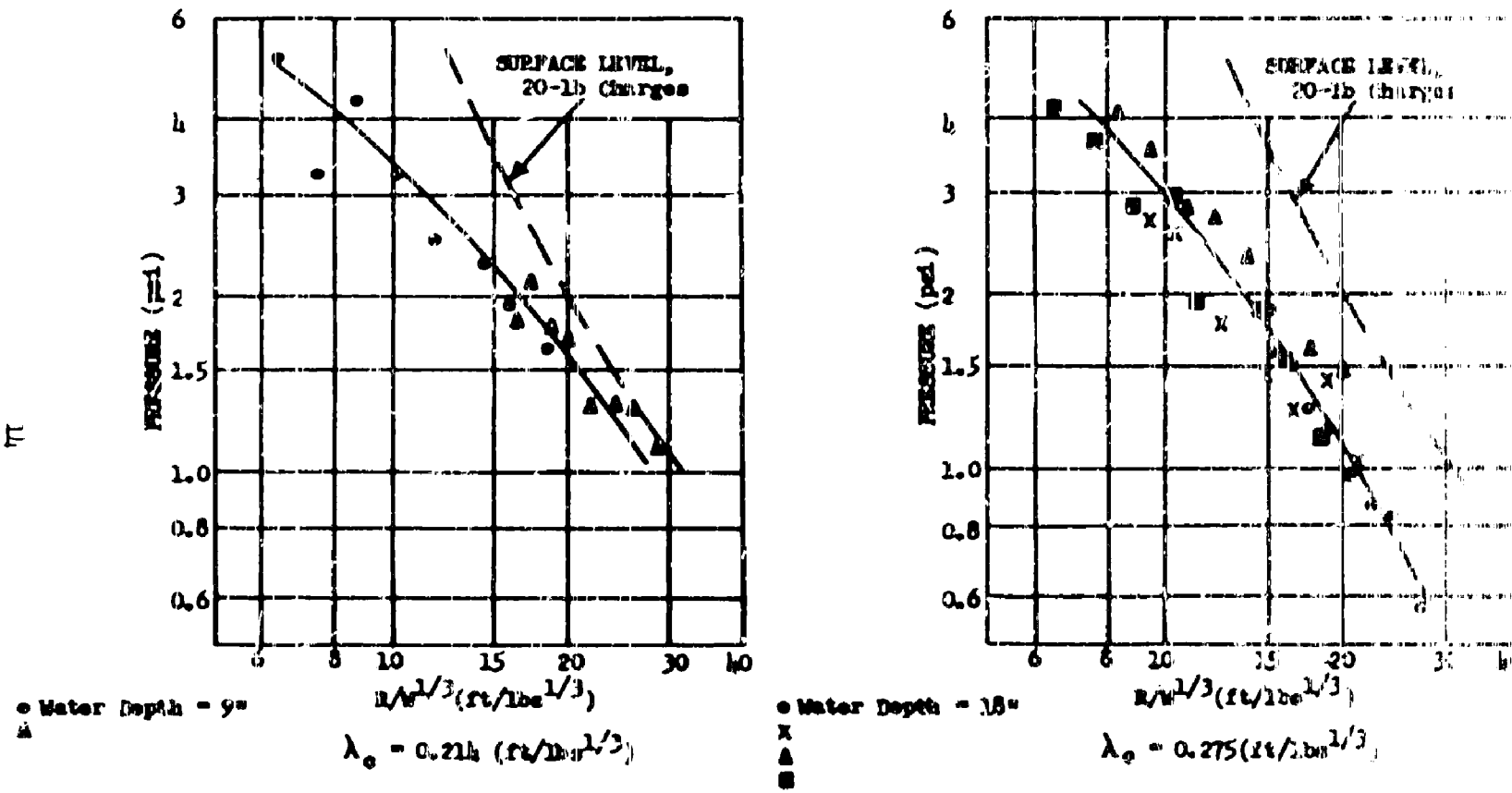
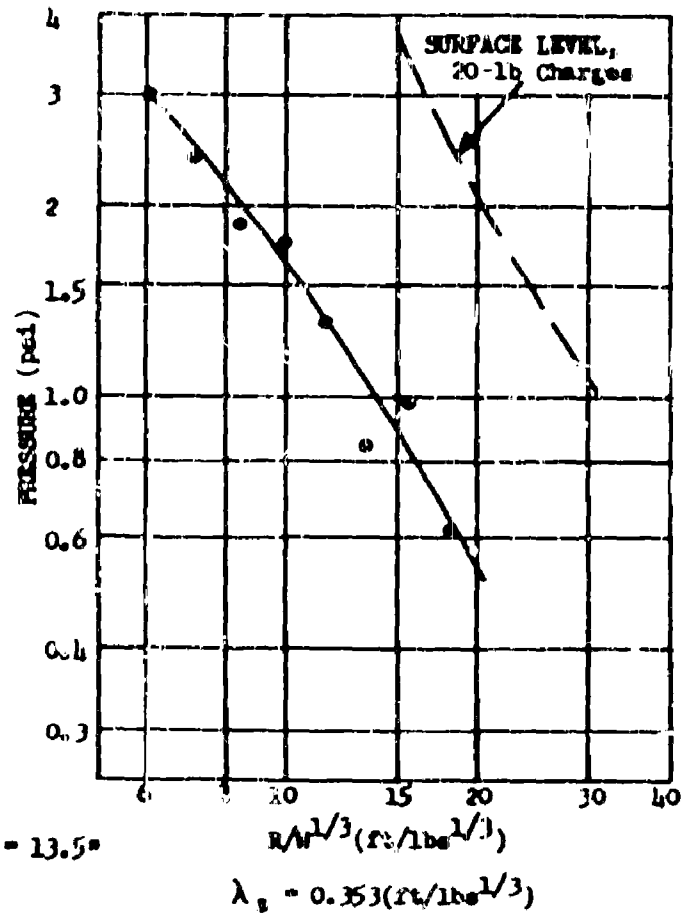
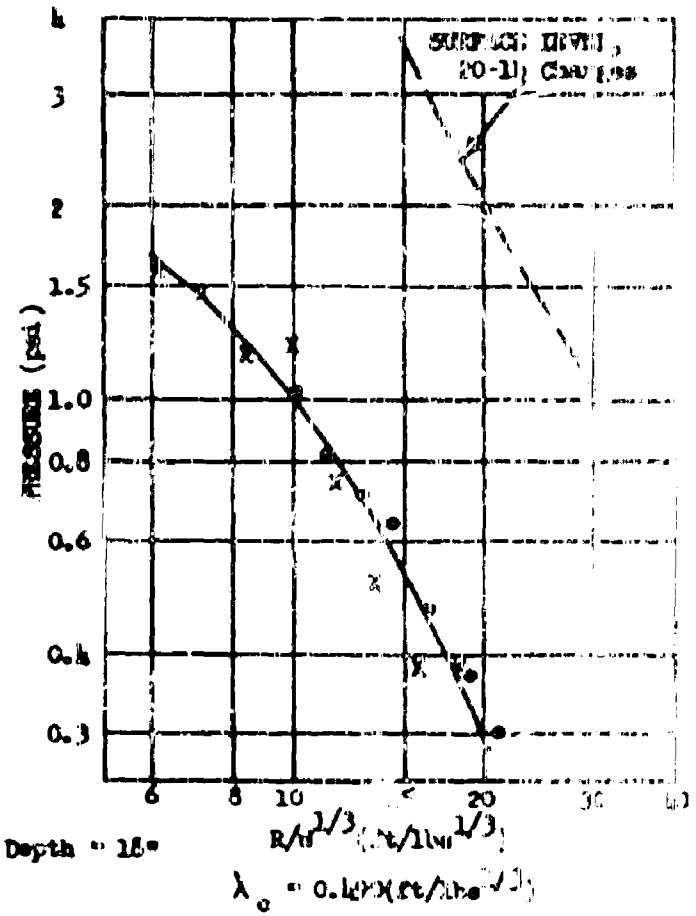


FIG. 9 PEAK PRESSURE vs REDUCED DISTANCE FOR 20-LB CHARGES



• Water Depth = 13.5"

$\lambda_s = 0.353 (ft/lbs^{1/3})$



• Water Depth = 18"

x

$\lambda_s = 0.429 (ft/lbs^{1/3})$

FIG. 10 PEAK PRESSURE vs REDUCED DISTANCE FOR 20-LB CHARGES

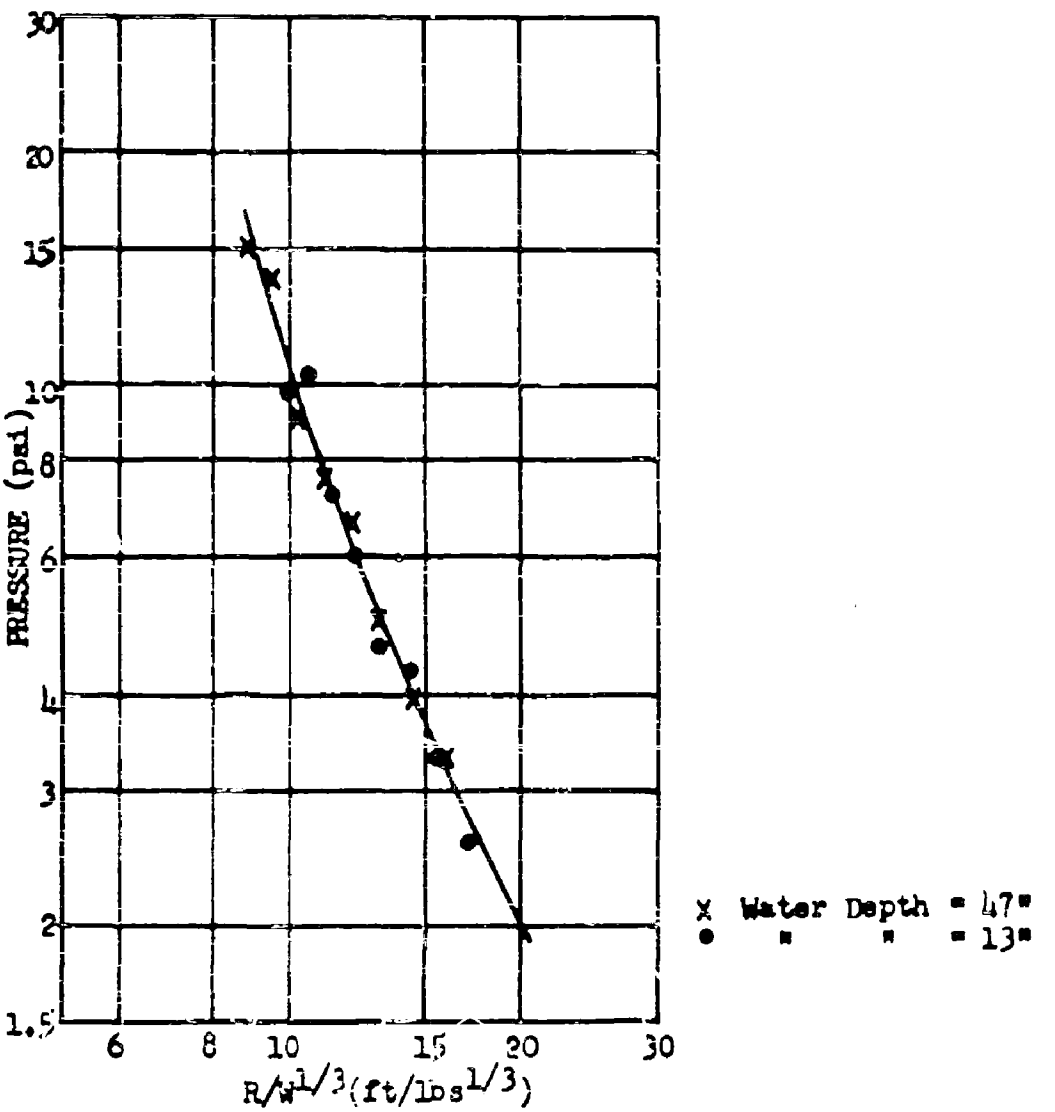


FIG. 11 PEAK PRESSURE vs REDUCED DISTANCE FOR 101-LB CHARGES
Bottom of Charge at Surface (Surface Level)

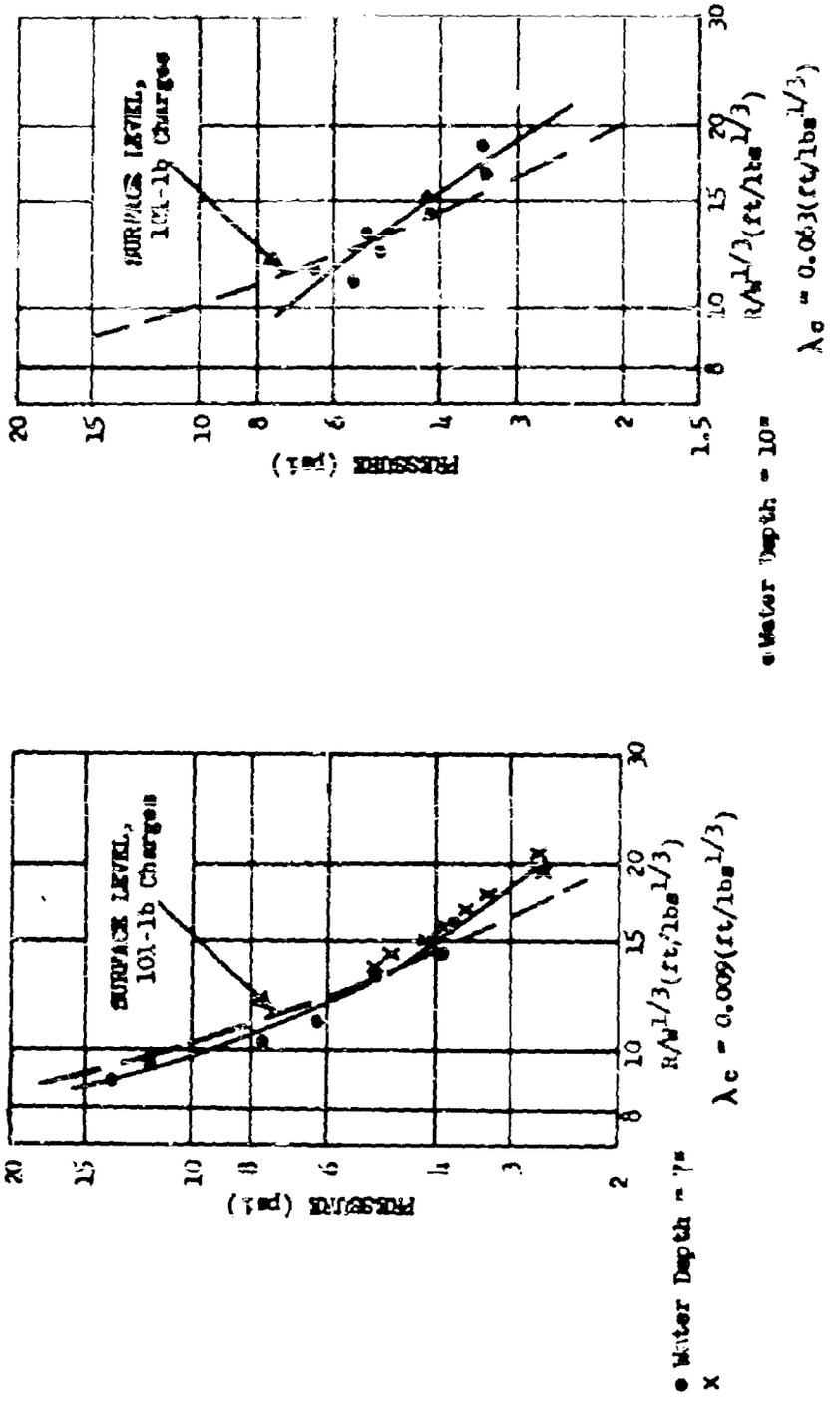
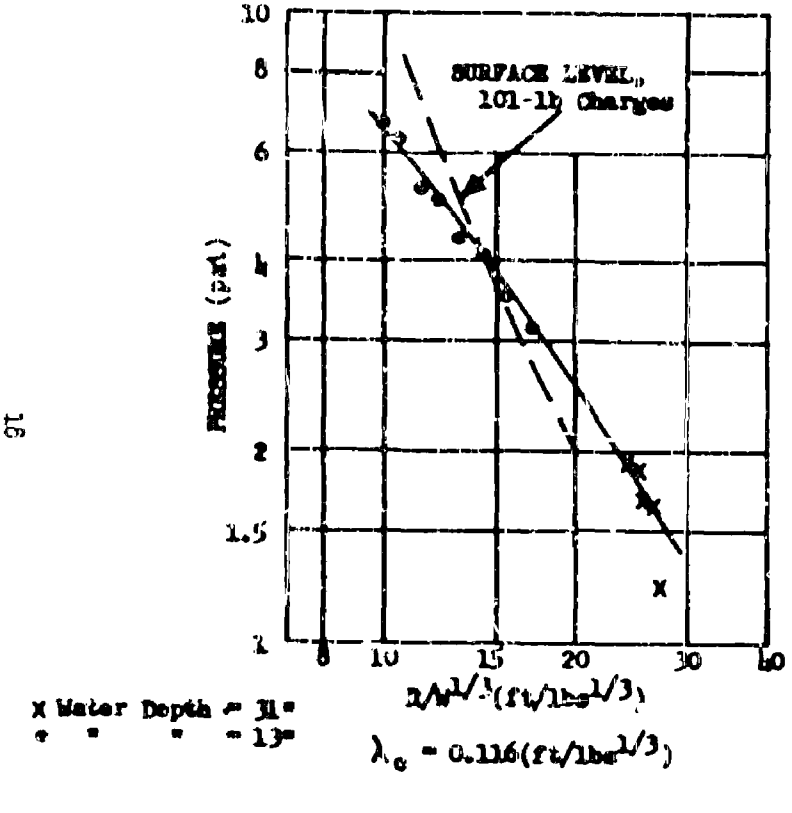


FIG. 12 PEAK PRESSURE vs REDUCED DISTANCE FOR 101-LB CHARGES



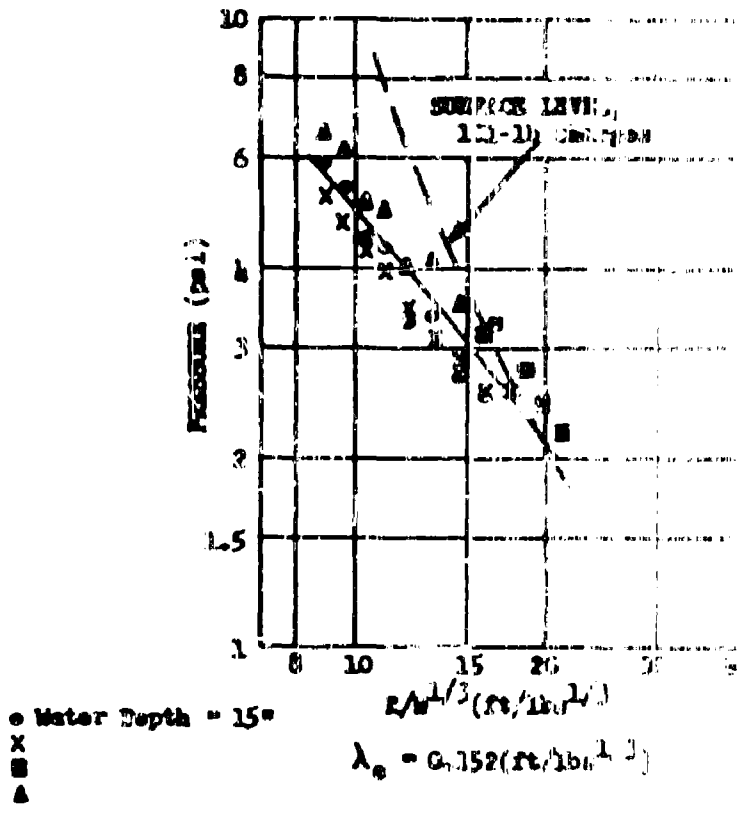
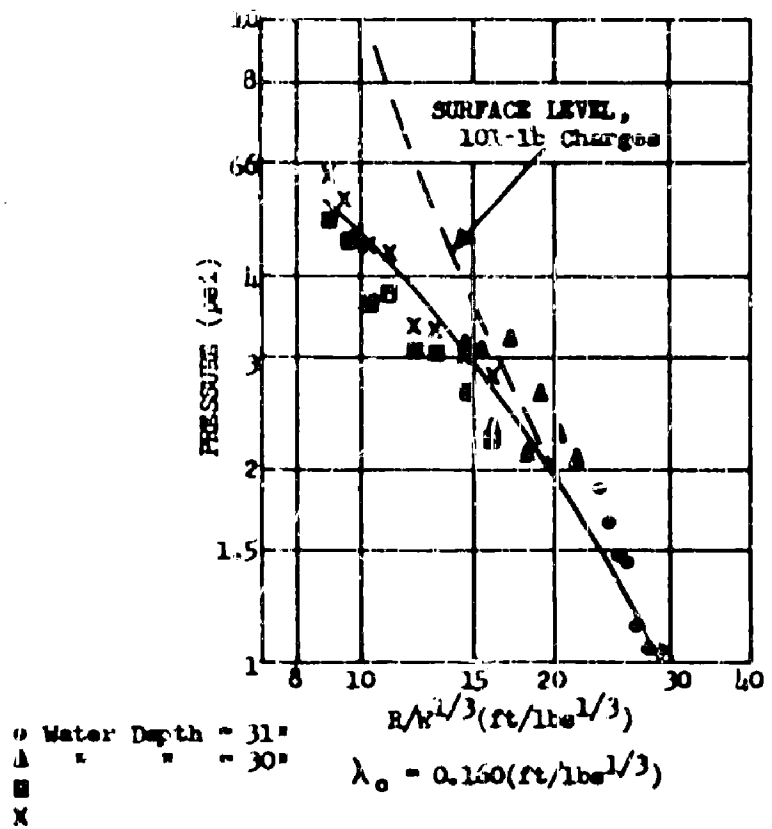


FIG. 13 PEAK PRESSURE vs REDUCED DISTANCE FOR 101-LB CHARGES



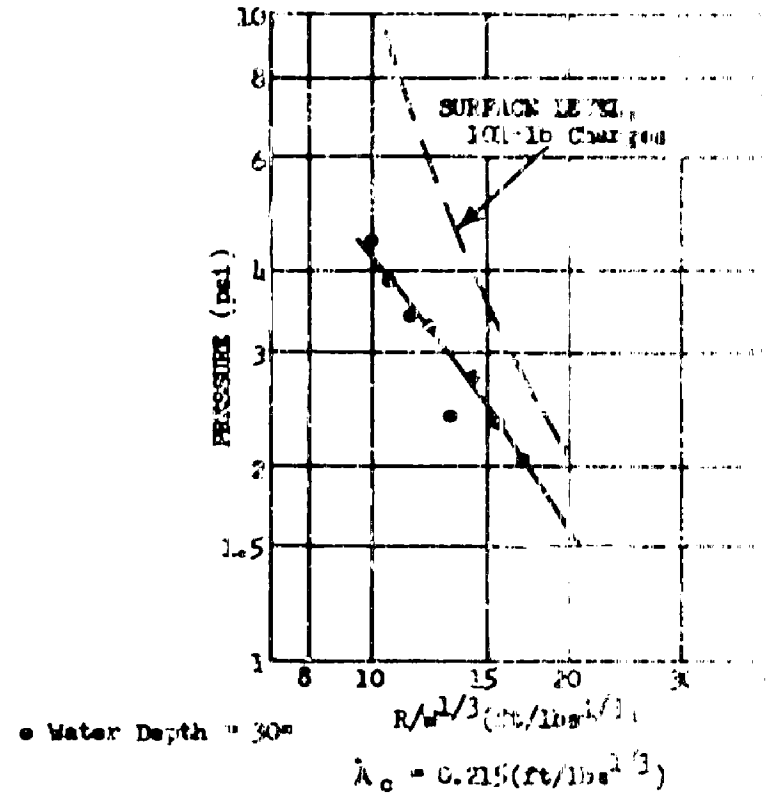
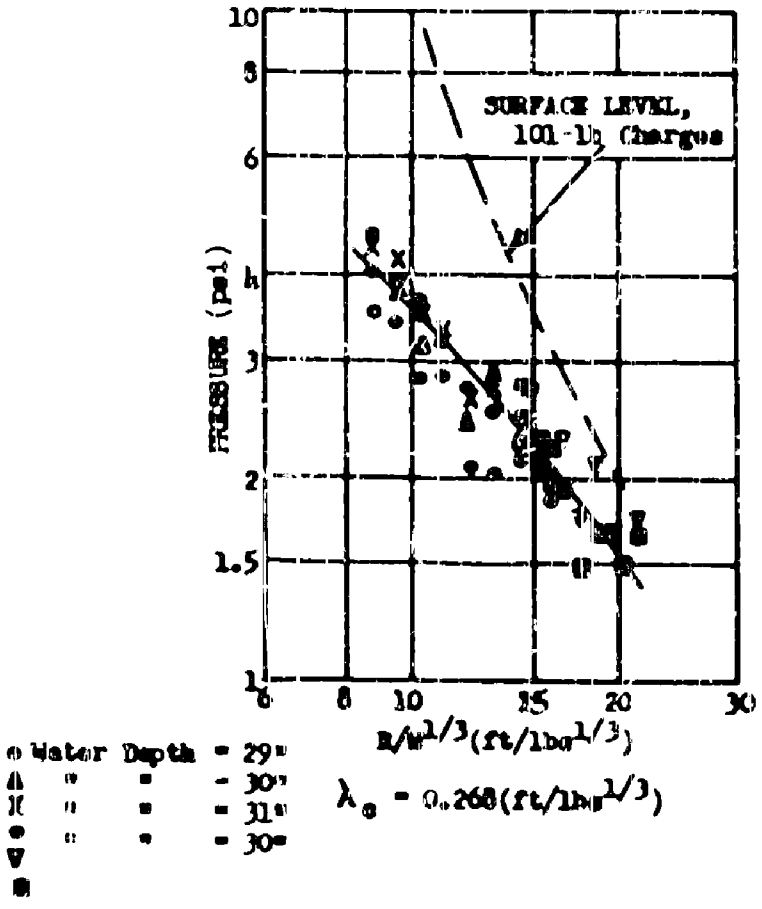


FIG. 14 PEAK PRESSURE vs REDUCED DISTANCE FOR 100-LB CHARGES



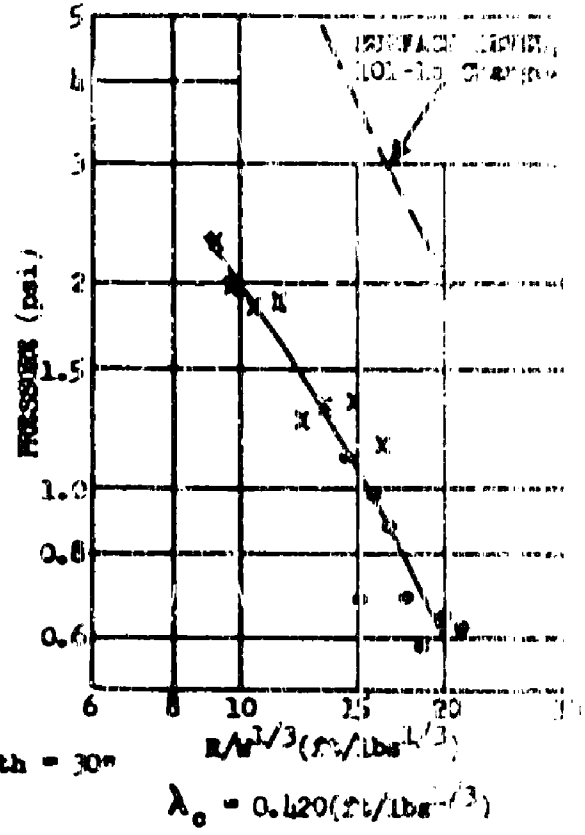
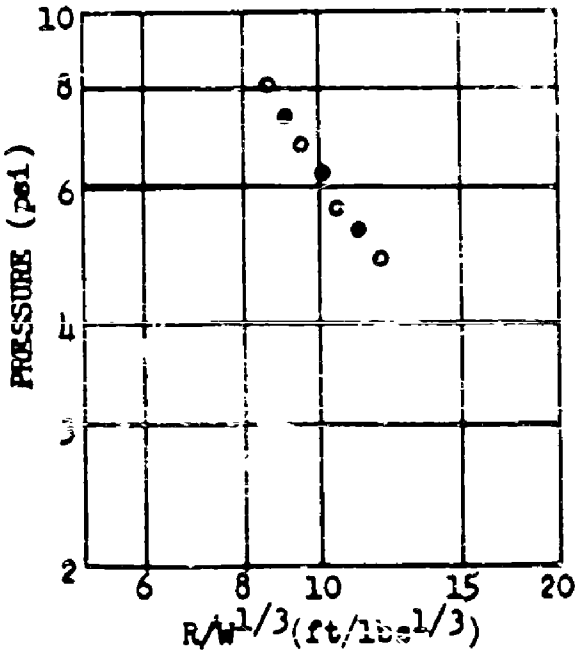


FIG. 15 PEAK PRESSURE vs REDUCED DISTANCE FOR 101-LB CHARGES

λ_o = 0.089
c 4" Gauge Height
● 15" " "



λ_o = 0.141
o 4" Gauge Height
● 15" " "

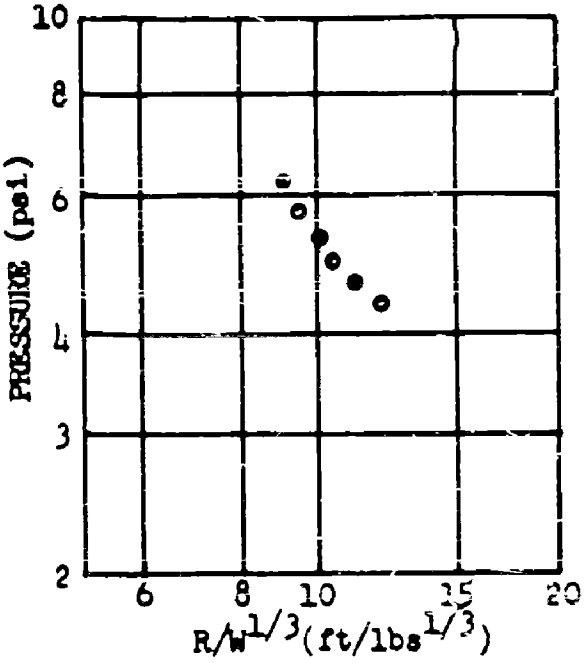


FIG. 16 PEAK PRESSURE vs REDUCED DISTANCE FOR 600-LB CHARGES

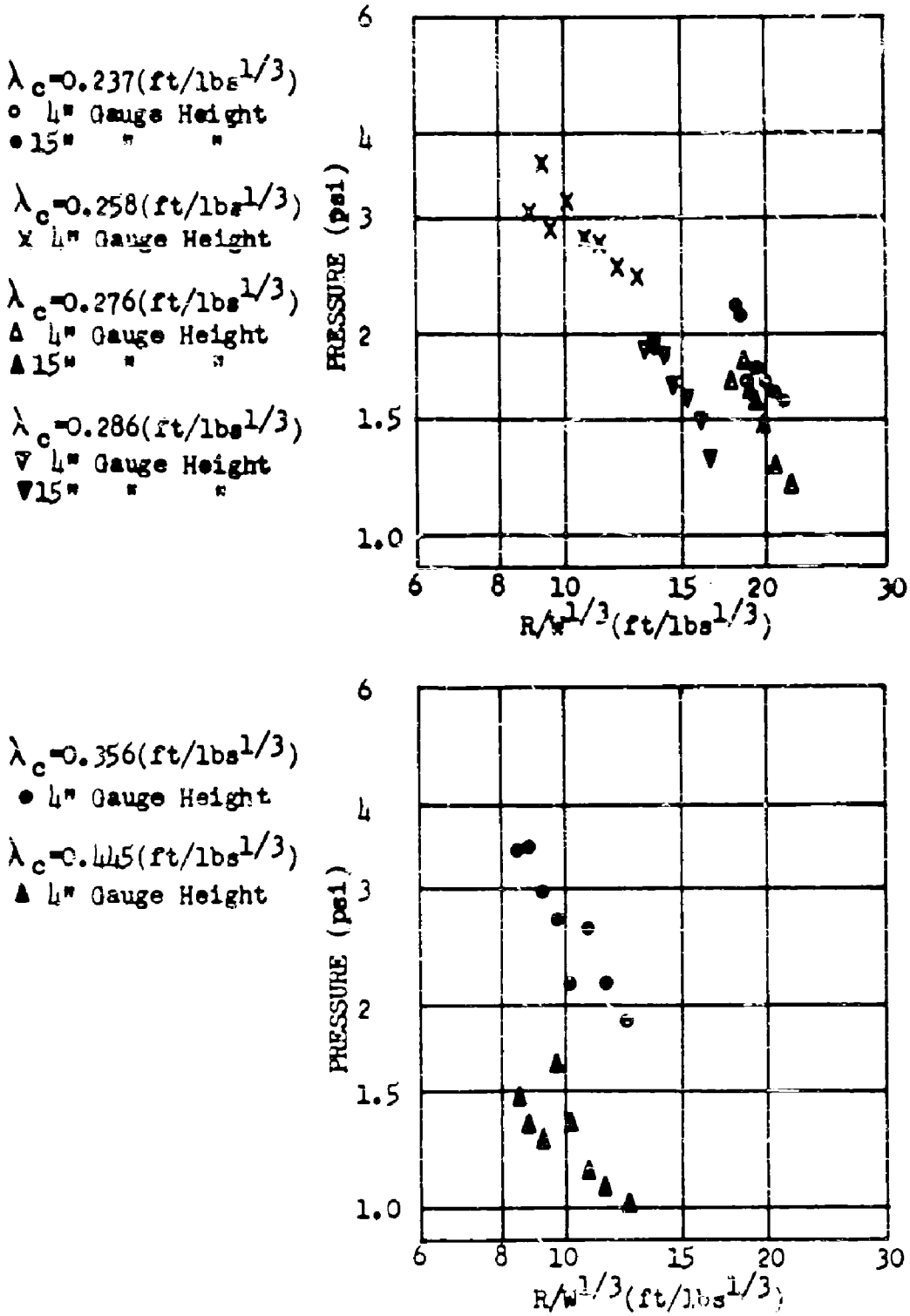
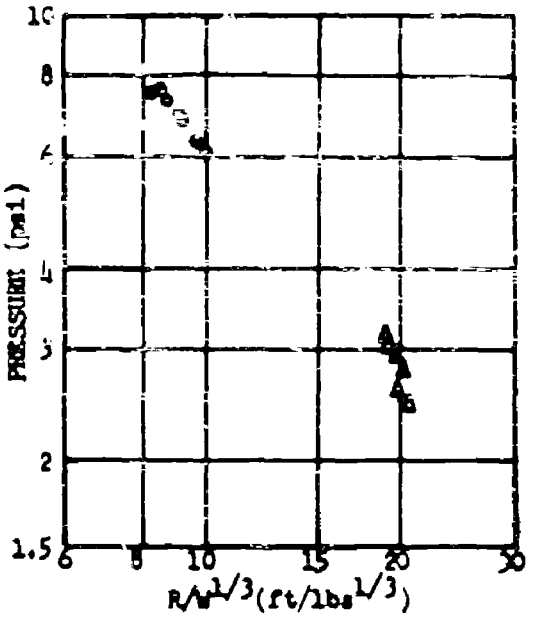


FIG. 17 PEAK PRESSURE vs REDUCED DISTANCE FOR 600-LB CHARGES

λ_c = 0.046(ft/lbs$^{1/3}$)
▲ 4" Gauge Height
▲ 15" " "

λ_c = 0.067(ft/lbs$^{1/3}$)
o 4" Gauge Height
• 15" " "



λ_c = 0.181(ft/lbs$^{1/3}$)
• 4" Gauge Height

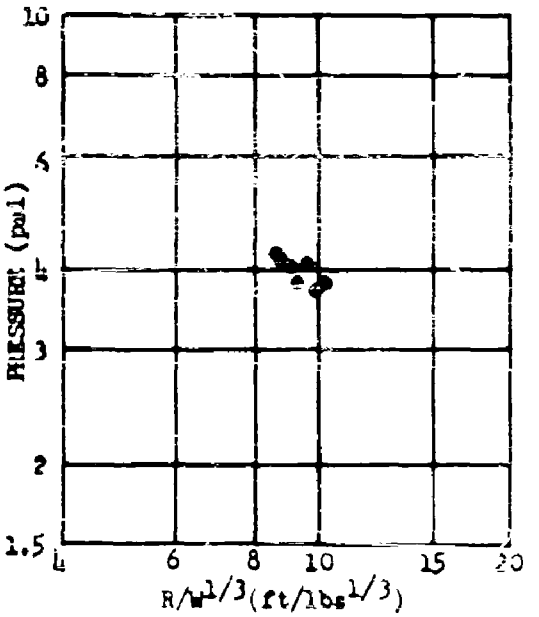


FIG. 18 PEAK PRESSURE vs REDUCED DISTANCE FOR 4200-LB CHARGE

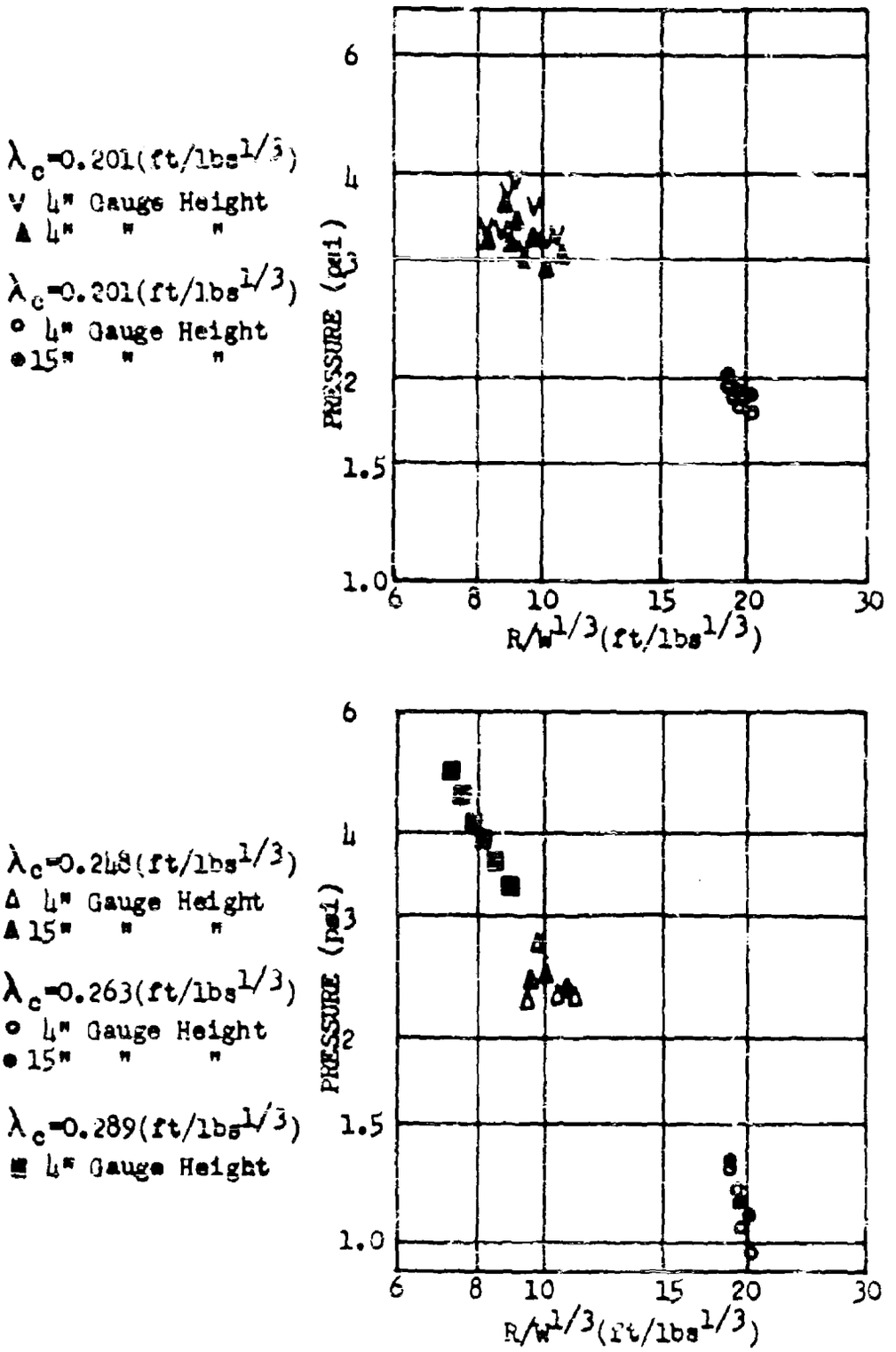
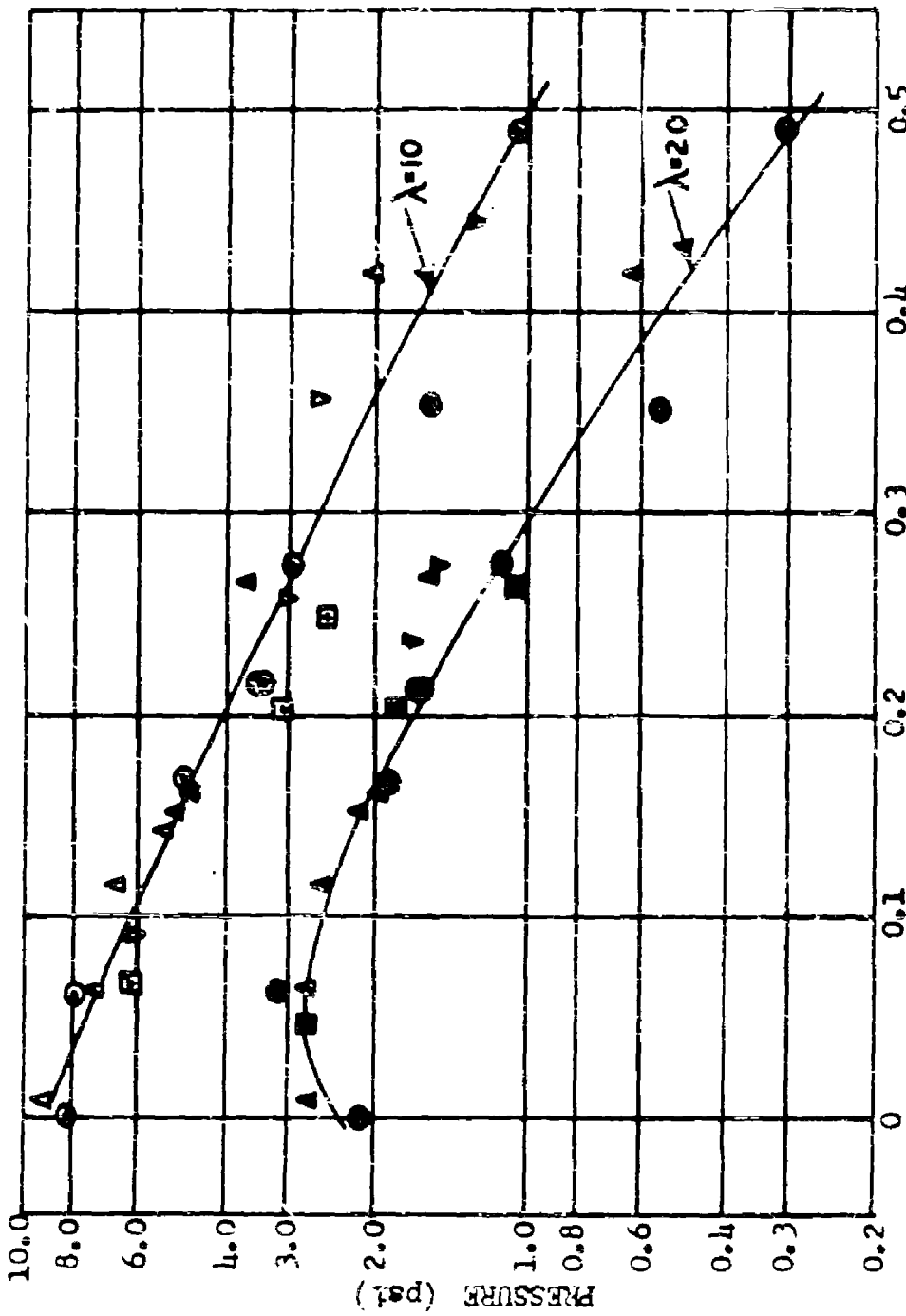


FIG. 19 PEAK PRESSURE vs REDUCED DISTANCE FOR 4200-LB CHARGES



$\lambda_o = R_c/W^{1/3}$ (ft/lbs$^{1/3}$)

FIG. 20 PEAK PRESSURE vs REDUCED CHARGE DEPTH

TABLE I

Peak Pressures from 20-Pound Charges

Charge** Depth (in.)	λ c ($ft/lbs^{1/3}$)	Water Depth (in.)	Parameter	Gauges at 4 Inches Height							
Surface* Level		60.0	R(ft)	19.5	23.0	27.0	31.5	36.5	42.5	49.5	
			P(psi)	21.7	13.3	9.60	5.93	4.32	3.26	2.37	
Surface* Level		48.0	R(ft)	19.5	23.0	27.0	31.5	36.5	---	49.5	
			P(psi)	24.3	14.6	9.43	5.57	4.51	---	2.23	
Surface* Level		36.0	R(ft)	21.5	24.5	28.0	32.5	37.5	43.5	50.5	
			P(psi)	16.1	12.0	7.06	4.14	3.67	2.52	2.23	
Surface* Level		25.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.07	3.30	2.82	2.91	2.20	2.08	1.94	1.44
Surface* Level		4.0	R(ft)	51.5	54.5	58.0	62.0	66.5	71.5	77.5	84.5
			P(psi)	2.52	2.13	1.72	1.84	1.05	1.01	1.01	0.76
0.0	0.0	18.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	3.22	3.63	2.45	2.36	1.61	2.00	2.04	1.47
0.0	0.0	18.0	R(ft)	17.0	20.0	23.5	27.5	32.0	37.0	43.0	50.0
			P(psi)	24.5	15.9	9.39	9.43	4.82	4.59	3.07	2.59
2.0	0.061	39.0	R(ft)	26.2	29.2	32.7	36.7	41.2	46.2	52.2	59.2
			P(psi)	8.35	8.30	6.39	5.29	3.83	4.37	3.09	2.56
2.0	0.061	4.0	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	13.0	12.1	8.45	8.79	4.51	5.57	5.09	4.32
2.0	0.061	4.0	R(ft)	46.5	49.5	53.0	57.0	61.5	66.5	72.5	79.5
			P(psi)	4.19	3.93	3.14	3.14	2.28	2.31	2.05	1.72
2.0	0.061	4.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.07	4.11	3.45	3.35	2.56	2.56	2.27	1.91
5.5	0.168	18.0	R(ft)	20.0	23.0	26.5	30.5	35.0	40.0	46.0	53.0
			P(psi)	6.02	5.59	4.49	4.37	3.23	3.13	2.63	2.30
5.5	0.168	25.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	2.83	2.54	1.91	1.88	1.55	1.52	1.33	0.98
5.5	0.168	23.5	R(ft)	26.5	29.5	33.0	37.0	41.5	46.5	52.5	59.5
			P(psi)	4.59	3.97	3.36	3.40	2.64	2.64	2.21	1.66
5.5	0.168	20.5	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	7.21	6.36	5.09	5.09	3.78	3.65	2.66	2.34

* Bottom of charge level with water surface.
** Charge Depth - from center of charge to water surface.

TABLE I (Con't.)

Peak Pressures from 20-Pound Charges

Charge** Depth (in.)	λc ($ft/lbs^{1/3}$)	Water Depth (in.)	Parameter	Gauges at 4 Inches Height							
7.0	0.214	30.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	2.78	2.30	1.80	1.77	1.41	1.37	1.12	0.91
7.0	0.214	18.0	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	4.83	4.32	3.57	3.23	2.47	2.24	1.92	1.53
7.0	0.214	15.0	R(ft)	46.5	49.5	53.0	57.0	61.5	66.5	72.5	79.5
			P(psi)	1.93	1.96	1.76	1.43	1.28	1.31	1.14	1.01
7.0	0.214	15.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	2.66	2.61	2.03	1.89	1.54	1.40	1.47	1.14
7.0	0.214	18.5	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	4.99	3.95	3.83	3.27	2.47	2.14	2.06	1.50
7.0	0.214	18.0	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	5.11	5.31	4.59	3.42	2.46	2.23	2.05	1.58
7.0	0.214	9.0	R(ft)	17.5	20.5	24.0	28.0	32.5	39.5	43.5	50.5
			P(psi)	5.20	3.26	4.32	3.26	2.50	2.28	1.92	1.63
7.0	0.214	9.0	R(ft)	44.5	47.5	51.0	55.0	59.5	65.5	70.5	77.5
			P(psi)	1.80	2.12	1.76	1.68	1.28	1.28	1.28	1.08
9.0	0.275	18.0	R(ft)	22.8	25.8	29.3	33.3	37.8	42.8	48.8	55.8
			P(psi)	4.07	3.54	2.80	2.70	2.33	1.59	1.62	1.48
9.0	0.275	18.0	R(ft)	25.5	28.5	34.0	40.5	45.5	51.5	58.5	
			P(psi)	2.72	2.60	1.79	1.46	1.28	1.43	1.04	
9.0	0.275	18.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	1.90	1.51	1.29	1.18	0.98	0.87	0.84	0.58
9.0	0.275	18.0	R(ft)	17.5	20.5	24.0	28.0	32.5	39.5	43.5	50.5
			P(psi)	4.21	3.76	2.85	2.97	1.97	1.91	1.55	1.15
11.5	0.353	13.5	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	3.00	2.37	1.87	1.75	1.32	0.84	0.98	0.62
16.0	0.490	18.0	R(ft)	16.5	19.5	23.0	27.0	31.5	36.5	42.5	49.5
			P(psi)	1.61	1.48	1.18	1.22	0.75	0.52	0.38	0.38
16.0	0.490	18.0	R(ft)	27.3	30.8	34.8	39.3	44.3	50.3	57.3	
			P(psi)	1.03	0.83	0.71	0.64	0.47	0.37	0.30	

** Charge Depth = from center of charge to water surface.

TABLE II

Peak Pressures from 101-Pound Charges

Charge** Depth (in.)	Ac (ft/lbs$^{1/3}$)	Water Depth (in.)	Parameter	Gauges at 4 Inches Height							
Surface* Level		13.0	R(ft)	44.5	49.5	53.0	57.0	61.5	66.5	72.5	79.5
			P(psi)	18.8	10.4	7.26	6.04	4.59	4.28	3.28	2.54
Surface* Level		47.0	R(ft)	44.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	18.0	13.7	9.14	7.72	6.72	5.06	3.98	3.33
0.5	0.009	7.0	R(ft)	44.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	18.6	11.9	7.32	6.26	5.19	5.04	3.92	3.76
0.5	0.009	7.0	R(ft)	64.5	66.5	70.0	74.0	78.5	83.5	89.5	96.5
			P(psi)	5.08	4.78	4.17	3.91	3.60	3.32	2.67	2.72
3.5	0.063	10.0	R(ft)	54.5	54.5	58.0	62.0	66.5	71.5	77.5	84.5
			P(psi)	8.52	6.50	5.09	5.28	4.09	4.24	3.38	3.41
6.5	0.116	31.0	R(ft)	115.5	115.5	119.0	123.0	127.5			
			P(psi)	1.98	1.90	1.68	1.65	1.22			
6.5	0.116	13.0	R(ft)	44.5	49.5	53.0	57.0	61.5	66.5	72.5	79.5
			P(psi)	18.6	6.37	5.21	5.09	4.38	4.12	3.55	3.17
8.5	0.152	15.0	R(ft)	44.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	18.5	6.02	5.04	4.97	3.99	4.02	3.49	3.13
8.5	0.152	15.0	R(ft)	70.0	77.0	81.5	86.5	92.5	99.5		
			P(psi)	3.11	3.26	2.56	2.75	2.42	2.20		
8.5	0.152	15.0	R(ft)	44.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	18.2	4.74	4.31	3.97	3.47	3.09	2.83	2.54
8.5	0.152	15.0	R(ft)	44.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	18.8	5.36	4.50	4.31	3.28	3.36	2.69	2.50
9.0	0.160	30.0	R(ft)	64.5	71.4	74.8	78.8	83.3	88.2	94.2	101.3
			P(psi)	3.11	3.07	2.30	3.19	2.11	2.59	2.23	2.07
9.0	0.160	31.0	R(ft)	104.5	112.5	116.0	120.0	124.5	129.5	135.5	
			P(psi)	1.88	1.65	1.47	1.44	1.15	1.05	1.05	

* Bottom of charge level with water surface.
** Charge Depth - from center of charge to the water surface.

TABLE II (Con't.)

Peak Pressures from 101-Pound Charges

Charge** Depth (in.)	λc ($ft/lbs^{1/3}$)	Water Depth (in.)	Parameter	Gauges at 4 Inches Height							
9.0	0.160	30.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	5.74	5.34	4.49	4.34	3.36	3.36	3.02	2.83
9.0	0.160	30.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.82	4.62	3.68	3.75	3.09	3.04	2.65	2.24
12.0	0.215	30.0	R(ft)	46.5	49.5	53.0	57.0	61.5	66.5	72.5	79.5
			P(psi)	4.43	3.77	3.43	3.31	2.38	2.76	2.34	2.05
15.0	0.268	32.0	R(ft)	67.5	70.5	74.0	78.0	82.5	87.5	93.5	100.5
			P(psi)	2.45	2.10	2.01	1.91	1.49	1.69	1.49	1.66
15.0	0.268	30.0	R(ft)	66.5	69.5	73.0	77.0	81.5	86.5	92.5	99.5
			P(psi)	2.75	2.65	2.34	2.28	1.75	2.10	1.67	1.75
15.0	0.268	30.5	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	3.55	3.43	2.79	2.83	2.09	2.05	2.17	1.85
15.0	0.268	31.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.46	4.27	3.55	3.36	2.66	2.80	2.44	2.32
15.0	0.268	30.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.02	3.73	3.13	3.20	2.43	2.82	2.30	2.24
15.0	0.268	29.5	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	4.65	3.96	3.62	3.21	2.70	2.51	2.18	1.93
23.5	0.420	30.0	R(ft)	41.5	44.5	48.0	52.0	56.5	61.5	67.5	74.5
			P(psi)	3.23	2.97	2.56	2.49	2.01	1.98	1.84	1.65
23.5	0.420	30.0	R(ft)	42.5	45.5	49.0	53.0	57.5	62.5	68.5	75.5
			P(psi)	2.35	1.98	1.88	1.88	1.26	1.33	1.33	1.16
23.5	0.420	30.0	R(ft)	66.5	69.5	73.0	77.0	81.5	86.5	92.5	99.5
			P(psi)	1.14	0.69	0.98	0.88	0.69	0 58	0.65	0.62

** Charge Depth - from center of charge to water surface.

TABLE III

Peak Pressures from 600-Pound Charges

Charges Depth (in)	λ_c ($ft/lbs^{1/3}$)	Water Depth (in)	Parameter	Gauges at 4 Inches Height				Gauges at 15 Inches Height		
9	0.085	22	R(ft)	73.0	80.0	89.0	101.0	76.5	84.5	95.0
			P(psi)	8.09	6.79	5.66	4.92	7.29	6.27	5.30
14	0.140	27	R(ft)	--	80.0	89.0	101.0	76.5	84.5	95.0
			P(psi)	--	5.73	4.97	4.36	6.24	5.28	4.66
24	0.237	51	R(ft)	153.0	160.0	169.0	181.0	156.5	164.5	175.0
			P(psi)	2.22	1.69	1.69	1.62	2.14	1.78	1.66
26	0.258	52	R(ft)	76.0	79.0	82.5	86.5			
			P(psi)	3.15	3.60	2.84	3.29			
			R(ft)	91.0	96.0	102.0	109.0			
			P(psi)	2.80	2.70	2.54	2.44			
28	0.276	42	R(ft)	153.0	160.0	169.0	181.0	156.5	164.5	175.0
			P(psi)	1.71	1.83	1.47	1.20	1.67	1.61	1.28
29	0.286	54	R(ft)	113.0	120.0	129.0	141.0	116.5	124.5	135.0
			P(psi)	1.91	1.89	1.62	1.32	1.94	1.69	1.51
36	0.356	49	R(ft)	71.5	74.5	78.0	82.0			
			P(psi)	3.41	3.43	2.98	2.72			
			R(ft)	86.5	91.5	97.5	104.5			
			P(psi)	2.17	2.60	2.17	1.91			
45	0.445	58	R(ft)	71.5	74.5	78.0	82.0			
			P(psi)	1.47	1.34	1.27	1.64			
			R(ft)	86.5	91.5	97.5	104.5			
			P(psi)	1.34	1.13	1.07	1.00			

* Charge Depth - from center of charge to surface

TABLE IV

Peak Pressures from 4200-Pound Charges

Charge* Depth (ft)	λc (ft/lbs$^{1/3}$)	Water Depth (ft)	Parameter	Gauges at 4 Inches Height				Gauges at 15 Inches Height		
9	0.046	22	R(ft)	303.0	310.0	319.0	331.0	306.5	314.5	325.0
			P(psi)	3.14	3.02	2.61	2.58	3.06	2.92	2.80
13	0.067	26	R(ft)	133.0	140.0	149.0	161.0	136.5	144.5	155.0
			P(psi)	7.58	7.30	6.84	6.08	7.66	7.04	6.36
35	0.181	48	R(ft)	134.5	138.5	142.0	146.0			
			P(psi)	3.61	4.53	4.18	4.06			
			R(ft)	150.5	155.5	161.5	168.5			
			P(psi)	3.71	4.21	3.52	3.64			
39	0.201	52	R(ft)	303.0	310.0	319.0	331.0	306.5	314.5	325.0
			P(psi)	1.94	1.97	1.83	1.80	2.01	1.90	1.90
39	0.201	52	R(ft)	135.5	139.5	143.0	147.0			
			P(psi)	3.25	3.64	3.15	3.38			
			R(ft)	151.5	156.5	162.5	169.5			
			P(psi)	2.99	3.19	2.87	2.99			
39	0.201	52	R(ft)	136.5	139.5	143.0	147.0			
			P(psi)	3.29	3.25	3.44	3.86			
			R(ft)	151.5	156.5	162.5	169.5			
			P(psi)	3.09	3.44	3.18	3.22			
48	0.247	99	R(ft)	153.0	160.0	169.0	181.0	156.5	164.5	175.0
			P(psi)	2.29	2.73	2.32	2.32	2.44	2.48	2.36
51	0.263	103	R(ft)	303.0	310.0	319.0	331.0	306.5	314.5	325.0
			P(psi)	1.26	1.18	1.04	0.97	1.31	1.14	1.11
56	0.289	102	R(ft)	118.0	122.0	126.5	131.5			
			P(psi)	4.92	4.57	4.14	3.95			
			R(ft)	137.5	144.5					
			P(psi)	3.64	3.35					

*Charge Depth - from center of charge to surface

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